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TECHNICAL REPORT ARCCB-TR-89017

# COMPRESSION MOLDING OF FIBER GLASS/EPOXY HANDGUARDS FOR THE SFLM ADVANCED COMBAT RIFLE



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| Composite Materials | Filament Winding |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A novel compression molding process was used to fabricate a lightweight, high-strength continuous filament fiber glass/epoxy handguard for the advanced combat rifle. This process involved placing a filament wound preimpregnated preform into a fiber glass/epoxy mold with a room temperature vulcanized (RTV) rubber top cover and subjecting it to an autoclave cycle. A well-compacted and durable structure was easily and quickly produced utilizing this technique.

## TABLE OF CONTENTS

Page



## LIST OF ILLUSTRATIONS

## INTRODUCTION

The task was presented by the Future Weapons Branch, U.S. Army ARDEC, Picatinny Arsenal, New Jersey, to the Advanced Technology Branch, Benet Laboratories, to fabricate a handguard for the serial flechette launch mechanism (SFLM) advanced combat rifle (Figure 1). This is an alternative to the existing design found on the current combat rifle, the M16. The handguard was made in two parts, joined together over the proper location on the barrel of the rifle, and held in position by end caps. These caps had a groove in them which accepted the end lips of the handguard halves and held the halves tightly together as well as in position. The handguard had to be lightweight, yet strong and durable to withstand the rigors of field use. The surface finish had to be smooth with well-defined corners, fillets, and rounds. The ability to resist moderate temperatures (150°F-200°F) was essential. Vent holes were allowed to relieve the heat buildup.

The proposed solution to the problem was to fabricate a fiber-reinforced plastic handguard which would be lightweight and stronger than the previous all-plastic handguard. There are several possible configurations including chopped fiber resin injection molding and cloth layup utilizing either prepreg or resin transfer molding. However, these processes required specialized and expensive equipment unavailable for this project.

Another novel idea was filament winding or braiding a preform and molding this preform to the proper shape. This concept, initialized by Plastics Technical Evaluation Center (PLASTEC), U.S. Army ARDEC, Picatinny Arsenal, New Jersey, involves the use of a triaxial braider to wet braid a tube or "sock." This resin-preimpregnated sock is folded lengthwise to form a double thickness preform, put into a specially designed mold, and cured. Under the action of pressure during the curing process, the braided material is compressed into the required shape and when completed the handguard half is removed, the flashing trimmed, and the vent holes drilled. The result is a molded part that contains very few free edges, namely just the ends. Free edges are the edges of a laminate that have been cleanly cut or sheared exposing the individual ply edges to the environment. By themselves and by the action of moisture intrusion these plies tend to separate causing delamination and part failure. The molded edges, however, do not delaminate.

This quick, easy, and inexpensive compression molding technique was the chosen method of manufacture. However, after initial experimentation with resin-impregnated braided fiber glass socks, it was found that they were extremely difficult to handle. The weave simply fell apart when handled, indicating the need for a more workable material form. The use of commercially available preimpregnated fiber glass roving to filament wind a preform was explored with success. The filament wound preform proved to be easy to work with, quickly produced, and could be refrigerated for extended periods of time.

## PROCEDURE

The compression molding technique involved placing a form of preimpregnated fiber glass/epoxy material into a mold. The mold was subsequently placed into an autoclave where heat and pressure were applied to compact and form the handguard half. The molds were made from a fiber glass/epoxy tooling material produced by Fiberite Corporation, Winona, Minnesota. The part and the fiber glass molds were the same material and had the same heatup and cooldown rate which provided good anti-distortion characteristics. The molds were also light and could easily be brought to temperature, thus saving labor and process time. A long tool life could be expected with these molds.

Since the mold had only three major components, the function was quite simple (see Figure 2). The mold body contained a female cavity surrounded by a channel which was ported to a vacuum pump. The cavity accepted the preimpregnated form and provided the proper dimensions to the finished part. An aluminum caul plate sat on a positioning shelf in the mold body and was used to provide a flat molded edge on the part. The vacuum channel was also ported to the vacuum pump through this plate. A room temperature vulcanized (RTV) silicone rubber top cover was then placed over the caul plate effectively sealing the part and vacuum chamber (see Figure 3). These were made by molding the RTV in plaster molds supplied by PLASTEC. The top cover provided the proper form for the inside of the handguard and was pliable allowing the external pressure from the autoclave to transfer to the part. The action of the vacuum chamber allowed any gasses generated during the curing process to bleed off.

The manufacture of the molds was a laborious, yet straightforward process. An aluminum master of the handguard half, supplied by PLASTEC, was used as a mold for the tool. This master was positioned onto an aluminum plate upon which bars were affixed to provide the vacuum channel in the tool (see Figure 4). After a release agent was sprayed onto the master, a gel coat of the special epoxy molding resin was applied. This was followed by several layers of both fine and coarse fiber glass/epoxy preimpregnated cloths that built up a mold thickness of about 0.25 inch. A debulking procedure was then performed on the uncured mold assembly to squeeze out trapped air and to compact the laminate. Following this, a more coarse prepreg cloth was applied and the part was prepared for curing under vacuum and pressure. Detailed information on the laminate and curing techniques can be found in Appendix A.

The molding preforms consisted of uncured preimpregnated continuous filament fiber glass/epoxy material with a forest green pigment. This roving was filament wound onto an aluminum cylinder of specific dimensions (see Figure 5) providing the proper size and shape for the preform. Two layers of ± 45-degree helical wraps were first applied. This wrap was subsequently parted in two by slicing the laminate lengthwise 180 degrees apart. The halves were then joined to make a preform four layers thick which was placed into the mold.

The raised portions of the handguards were finger grips and were made in a unique way. A 0.25-inch thick layer of 90-degree wrap was wound onto the aluminum cylinder. This layer was then sliced into 0.25-inch wide ring segments which were removed from the cylinder, cut into approximately 2-inch lengths, and inserted into the finger grip grooves in the mold prior to the insertion of the preform. Under the heat and pressure of the curing process these ring segments were formed into the shape of the finger grips and bonded securely to the main body of the part.

As noted in the detailed drawings in Appendix B, the upper portion of the handguard was thicker than the rest of the part. This was accounted for by adding extra prepreg material in that area of the mold in the layup phase. A 0.5 by 0.25-inch strip of unidirectional preimpregnated fiber glass/epoxy, referred to as a rib, was laid into the mold, sandwiched between the two layers of the preform, and extended its entire length. This provided the required thickness for the top of the handguard and also gave longitudinal strength and stiffness.

The three parts of the handguard before cure, the preform, the finger rings, and the rib, were positioned into the mold using heat from a hot-air heat gun to soften the prepreg material to the point where it could be worked into the mold shape (see Figure 6). The excess material extending beyond the upper flat surface of the mold was cut away with a razor. Care was taken to ensure that an adequate amount of the prepreg material extended into the zone of the end lip, since this lip alone held the handguard halves together and onto the gun. When the preform, rings, and rib were positioned and worked to remove excess air pockets, the aluminum caul plate and the RTV top cover were installed. It should be noted that the caul plate not only provided a flat molded surface for the halves to be joined, but also formed the positioning holes required to properly position the halves onto the gun. This was accomplished by inserting four pins in the caul plate at the proper location.

When assembled, the molds were put into an autoclave in a group of four to cure the part. The cure cycle involved heating to 250°F while maintaining a pressure of 100 psi in a nitrogen environment. The molds were then disassembled, the handguard halves removed, and the flashing trimmed. The completed handguards are shown in Figures 7 and 8.

The drilling of the vent holes and the installation of internal heat shields were performed by the Future Weapons Branch. These heat shields provided protection from excessive heat buildup during firing. Also, the vent hole edges were sealed with an epoxy resin to prevent delamination.

## RESULTS

The compression molding procedure produced a solid, well-compacted handguard with a good surface finish and well-defined corners and rounds. The finger grips bonded securely to the body and blended in very well. Good end lip integrity was evident with fibers extending into this zone providing the required strength. This was verified by subjecting the handguard half to a simple three-point compression test with the end lips supported as shown in

Figure 9. A 355-pound load was required to initiate failure of the part with a midpoint deflection of 0.45 inch. This should give some indication of its strength and durability. The handguard weighed only 134 grams per half, meeting the lightweight criterion.

The compression molding technique produced a good quality part that conformed to all critical design tolerances. Slight dimensional instability resulted from the use of the flexible RTV silicone rubber top cover, but this did not affect the function or appearance of the handguard and could be neglected. An extremely slight axial bow was discovered that produced a small gap at both ends between two mating handguards. This was traced to residual stresses produced by the mold cure cycle which distorted the mold. However, when the handguards were assembled onto the rifle, this axial bow proved to be beneficial by providing a spring effect that tightened the coupling with the metal end caps. This allowed the handguards to mate together very well when installed on the rifle.

## CONCLUSIONS

The compression molding process successfully provided a well-compacted structure adhering to strict dimensional tolerances. The fine details of the handguard were generated without difficulty and without resin or fiber-rich areas. The novel approach of filament winding a continuous filament fiber glass/epoxy preimpregnated preform with integrated finger ring portions proved to be an easy, although laborious procedure. Mold wear was evident early in mold production, but this was due to inadequate part extraction techniques. However, when these were corrected, the molds showed little wear and could be expected to produce hundreds of parts before replacement.

It should be understood that the process described herein was experimental with the objective to produce a small quantity of a newly designed part. Major production of a continuous filament/plastic handguard may be accomplished in a much more inexpensive and timely manner. However, this process was accomplished in the projected time and cost frames, which was the objective here. The compression molding process produced a good quality, lightweight, and strong fiber glass/epoxy handguard.

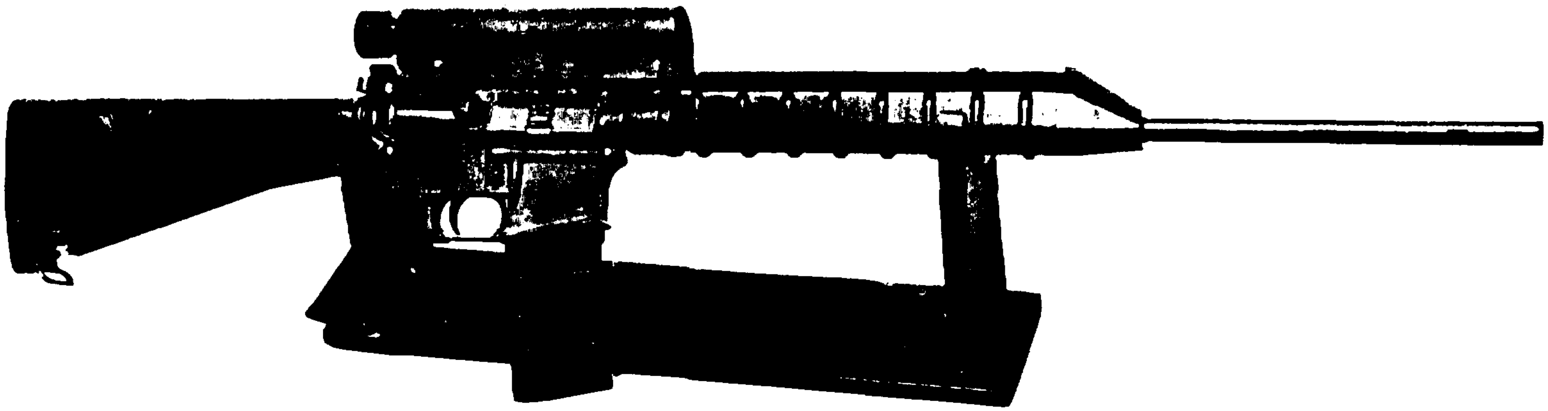

Figure 1. The serial flechette launch mechanism advanced combat rifle.

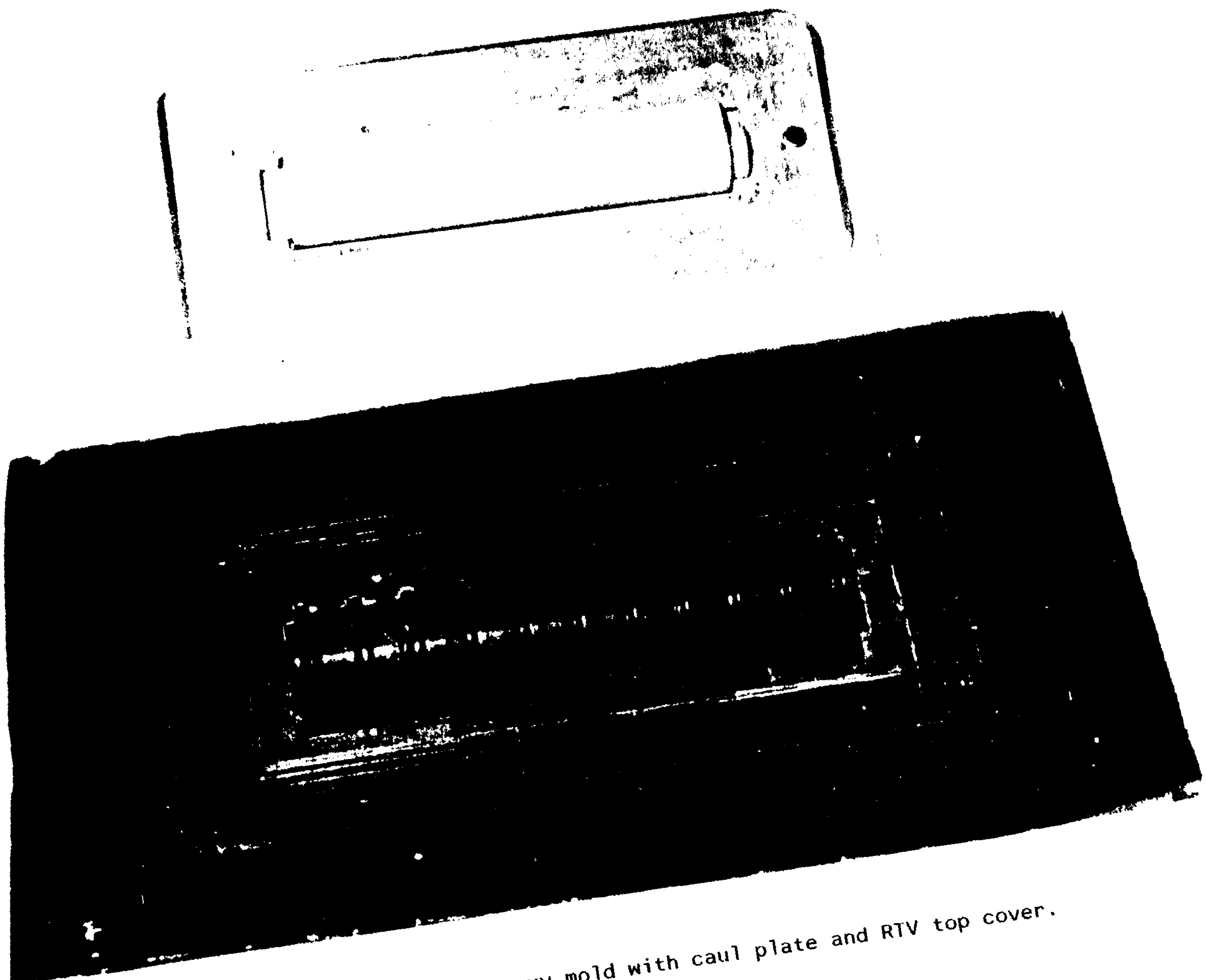

Figure 2. The fiber glass/epoxy mold with caul plate and RTV top cover.

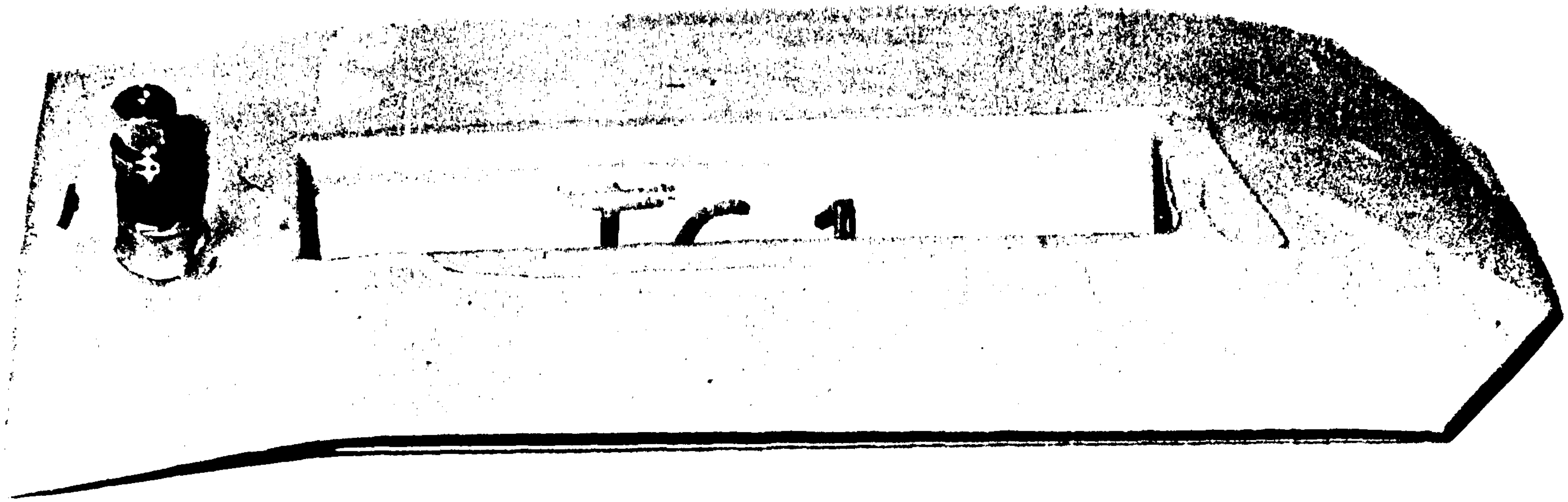

Figure 3.  RTV top cover and vacuum port.

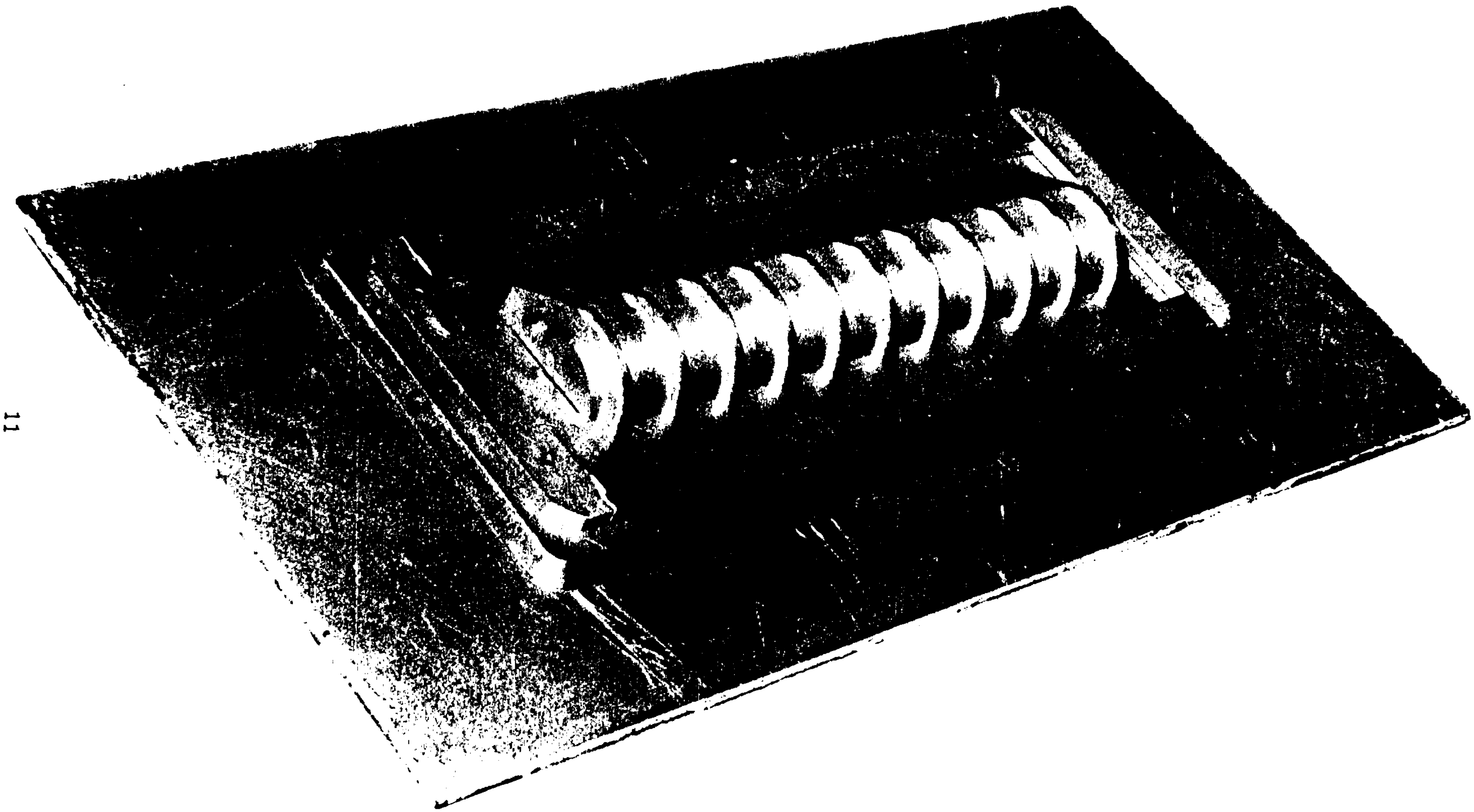

Figure 4. The aluminum master used to make the molds.

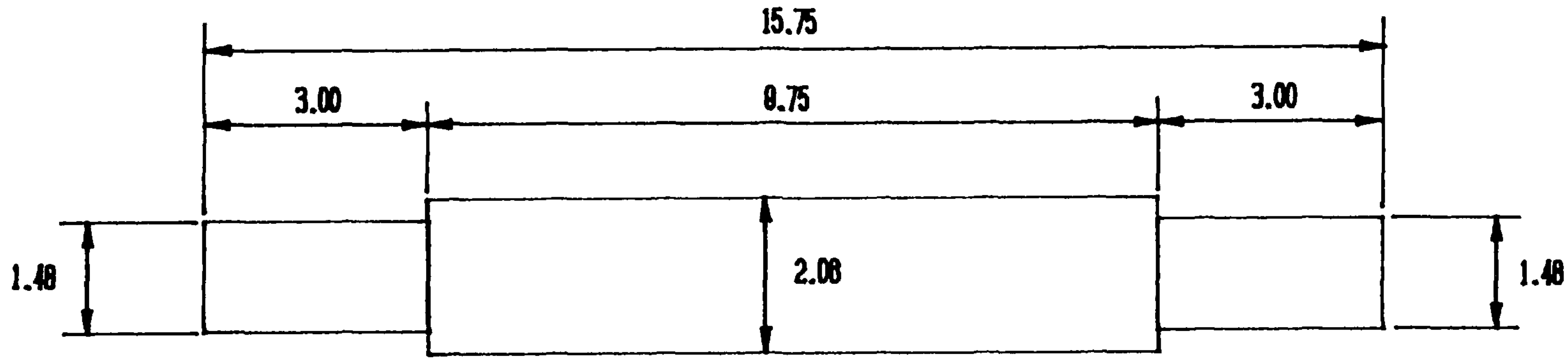


Figure 5. Dimensions of the aluminum preform mandrel.

Figure 6. The preimpregnated preform and finger rings ready to be placed in the mold.

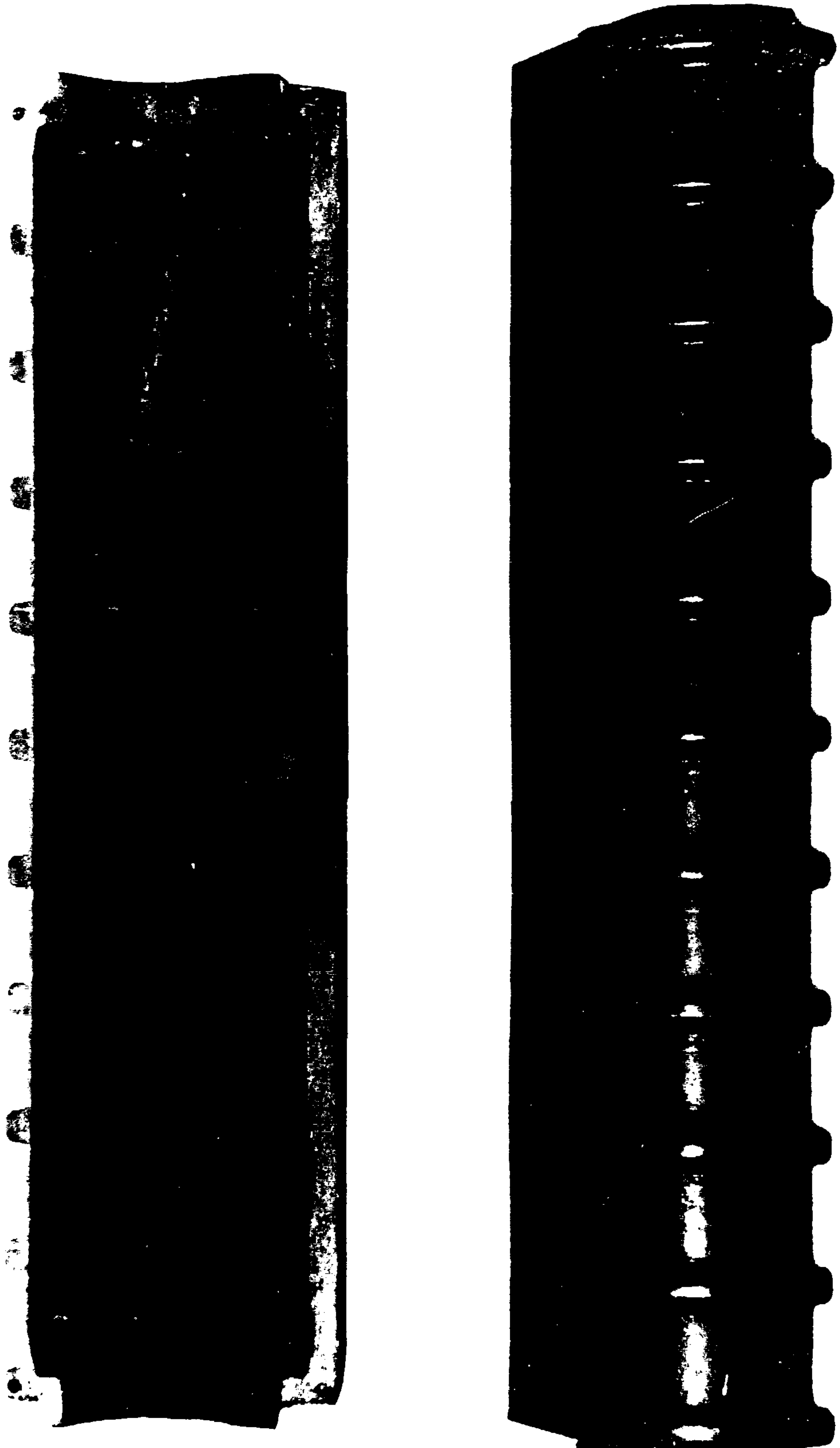

Figure 7. Completed handguard halves.

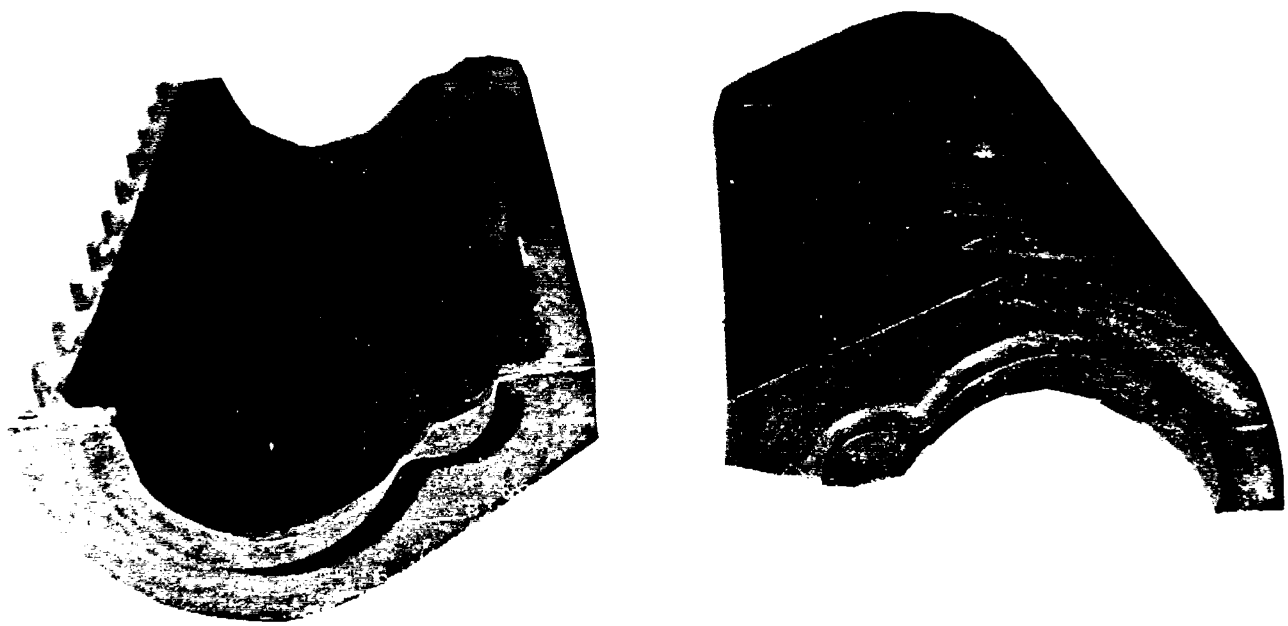

Figure 8. Completed handguard halves.

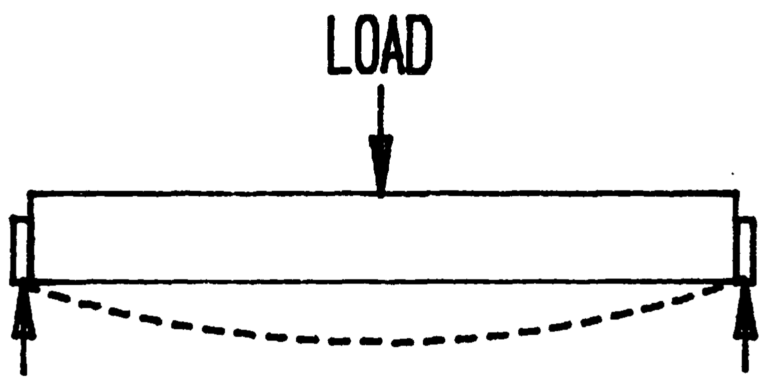


Figure 9. Handguard half subjected to three-point bend test.

## APPENDIX A

### Material

Preform, rings, and rib:

E-glass continuous filament preimpregnated with Fiberite Corp. 7714 forest green-pigmented epoxy resin.

Molds:

Fiberite Corp. Toolrite tooling molding system containing MXB-7620/7500 and MXB-7620/1597 preimpregnated cloth and MXR-7675 and MXR-7676 gel coat resin.

### Autoclave Procedure

Molds:

Debulk with 20-inch vacuum at 150°F for 1 hour. Cure under 20-inch vacuum and 100 psi pressure at 200 to 210°F for 4 hours. Postcure mold unsupported at 150°F for 1 hour, 200°F for 1 hour, 275°F for 1 hour, and 350 to 375°F for 2 hours.

Handguards:

Apply 20-inch vacuum and 100 psi pressure. Heat to 250°F and hold for 2 hours.

## APPENDIX B

### Detailed Drawings

This appendix contains the front and side view sketches of the handguard half.

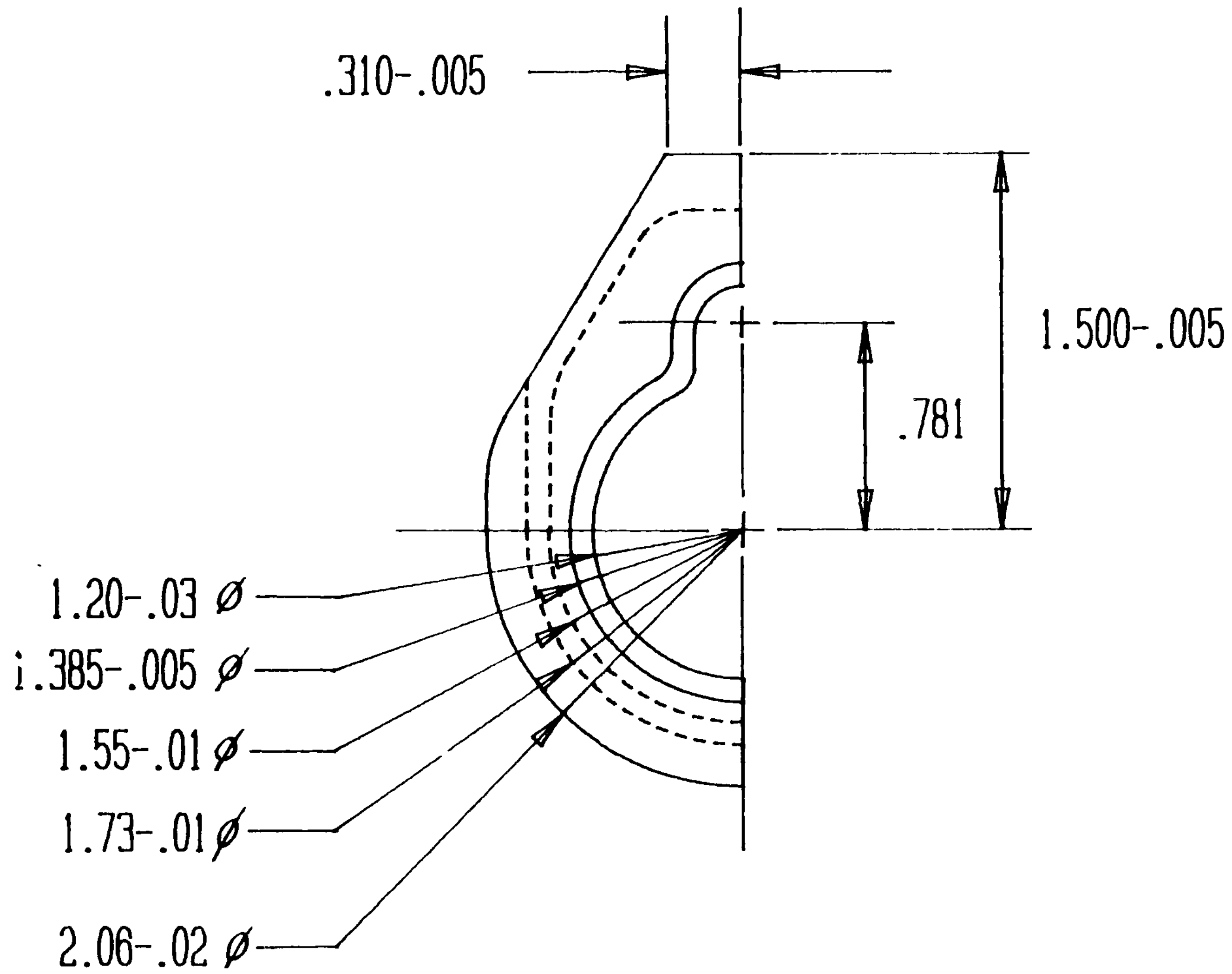


Figure B-1. Front view of the handguard half.

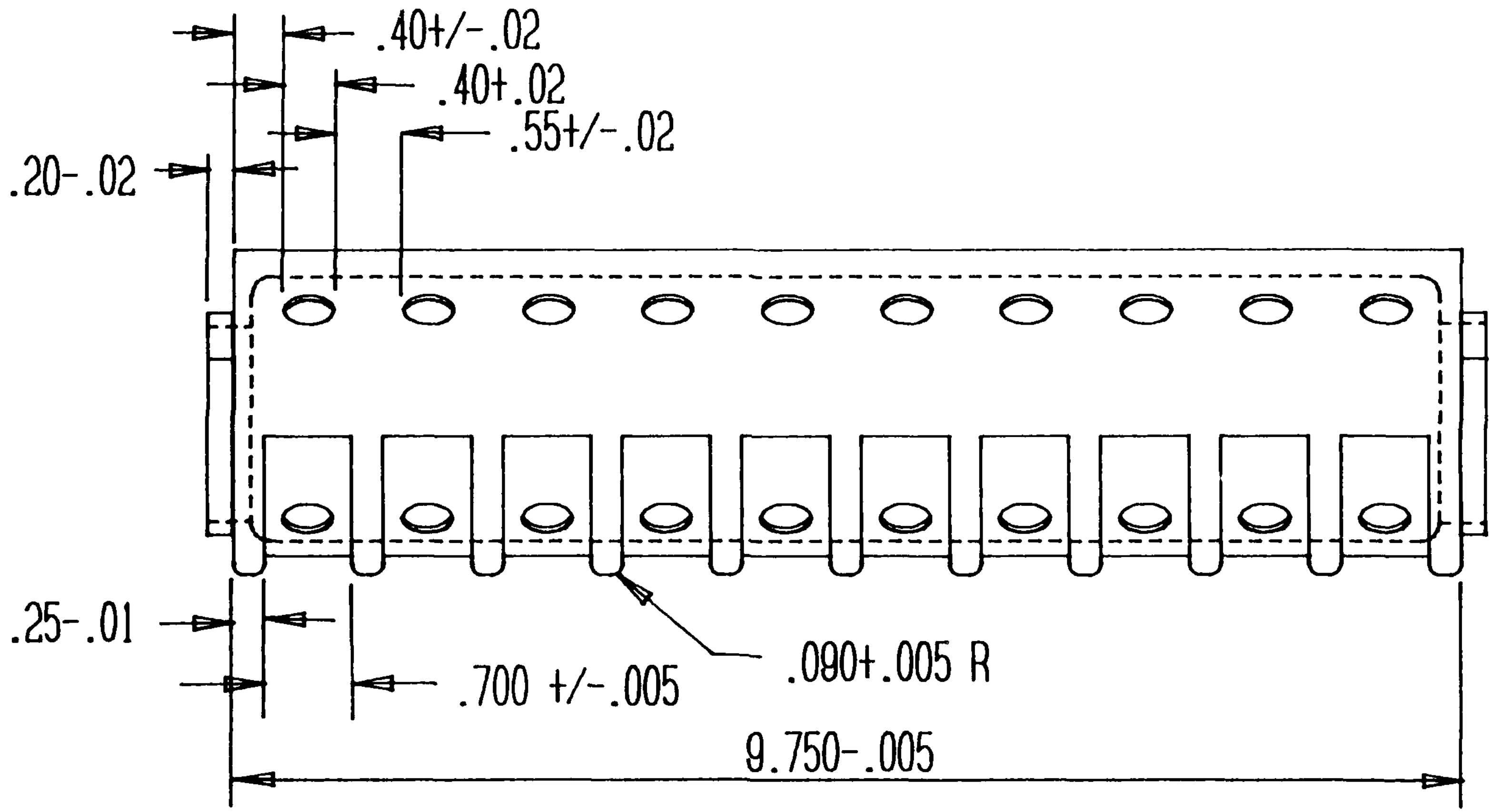


Figure B-2. Side view of the handguard half.

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